Standardized Procedure to Test the Strength of Solder Joints Formed with Rigid Lead Devices

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ABSTRACT: Tensile lead pull strength is an important characteristic of SMT solder joints that can be consistently measured using the general procedure described in this document. This procedure can be used to support process development and process control activities by comparing pull strength values obtained from using different reflow methods or by comparing the values historically.

APPLICABILITY: This procedure should be used by laboratory and process development and/or support personnel for module process development and control activities.

STATUS: APPROVED 27-Jul-1992; use VTX SMC for current status.

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1 INTRODUCTION

The integrity of solder joints formed between surface mount technology (SMT) components and substrates is critical to module reliability since they provide both mechanical and electrical connection. Tensile lead pull test procedures allow for strength values to be determined for a particular process. Stresses imposed upon the solder joints during this test differ from those that are seen under actual operating conditions. However, the information that is obtained is necessary for characterizing manufacturing processes.

1.1 PURPOSE

This document defines the process used to find the strength of the solder joint between rigid leads on SMT devices and bonding pads on printed-wiring boards (PWBs). This test is useful as a comparison between bonding processes and materials for a given component family.

1.2 GENERAL CONCEPT

Several methods of evaluating the quality of a solder joint are available, such as:

Visual inspection
Microsection evaluation
Electrical tests
Mechanical tests

Destructive mechanical inspection is necessary to augment the other tests and fully qualify the integrity of the joint. This inspection is completed by securing a single lead and breaking the bond that holds it to the solder joint using a machine capable of good force sensitivity, such as an Instron Mechanical Series 112x or the equivalent.

Note that both *peel tests* and *pull tests* are done with this one test. The only difference is peel test addresses the fact that the steady-state force region (the force to *propagate* a crack) is being analyzed, while pull test addresses the analysis of the initial peak force (the force to *initiate* this crack). This procedure primarily covers the acquisition of the pull force, while the peel force acquisition needs to be addressed using a separate test method that includes tests for flexible leads, for example, tape automated bond/bonding (TAB).

2 EQUIPMENT/SUPPLIES

Equipment and supplies needed to perform solder joint testing are described under the following subheads.

2.1 EQUIPMENT

Instron Series 112x or an equivalent tensile testing machine capable of at least 50 grams full-scale resolution can be used to test solder joints. The output must be a load-time (or load-deflection) curve. Computer control, such as that accomplished through the Instron Series IX software package, is strongly recommended but not necessary.

2.2 SUPPLIES

A list of the recommended supplies needed to perform solder joint tests follows.

a. Load cell capable of measuring forces between 0.1 and 15.0 lb. (Either a 100 N or 50 lb tension cell is acceptable. Resolution of force must be at least 0.1 lb.)

b. Several different types of air-activated grippers are available, but the chosen gripper should not apply a torsional force to the solder joint when clamping is performed.

c. Constant angle peel fixture with moveable x-y table and clamps to affix module/coupon to it.

d. Light source that illuminates solder joints during testing is helpful.

e. Vision system to improve ease-of-testing leads (either a stereomicroscope mounted to the frame or a CCD camera is acceptable).

f. Equipment for excising package body from the lead frame: a laser is recommended, but a slow-speed, oil-cooled diamond saw is acceptable for rigid leads as small as 25 mil pitch.

g. Cutting supplies (either a high-speed Dremel or a diamond saw) for excising the component footprint from the PWB (optional).

3 PROCEDURE

The procedure includes instrument setup, sample preparation, and the actual testing. Each process is detailed in the following subheads.

3.1 INSTRUMENT SETUP

1. Mount, calibrate, and balance the load cell as recommended by the equipment manufacturer.
2. Bolt the constant angle peel fixture to the lower base plate. Attach the retaining wire from the moving stage of the fixture to a bar extending from the back of the crosshead. This wire is used to keep the sample movement synchronous with the crosshead motion, so it must be aligned accordingly.

3.2 SAMPLE PREPARATION

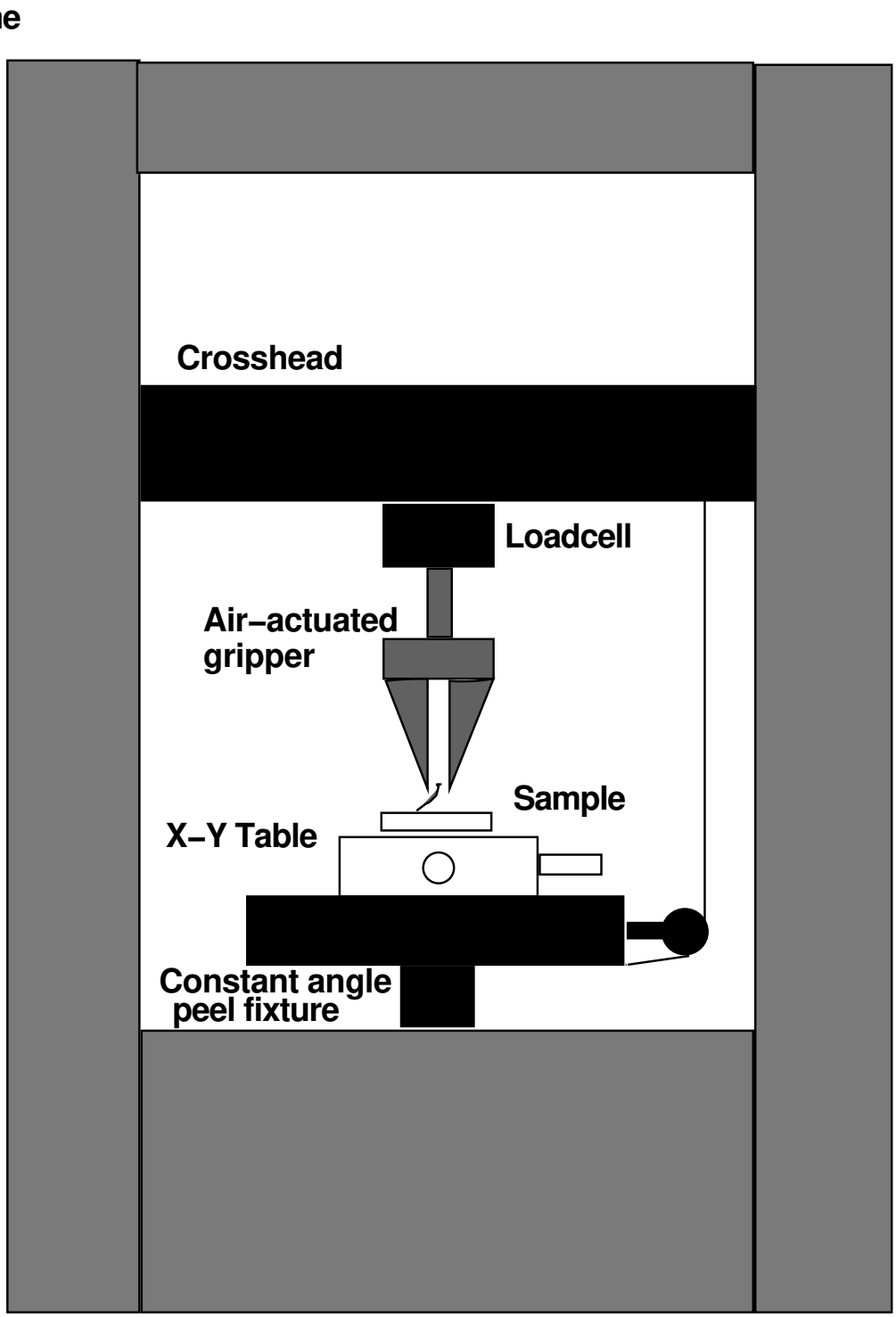
1. Remove the package from the module either by laser excision or by a slow-speed, oil-cooled diamond saw. Either technique is nondestructive to the solder joints, provided care is taken to protect the freestanding leads.

CAUTION

Both techniques, when *improperly* performed, are capable of damaging the solder joints. In particular, excessive heat, force, or vibration near the solder can affect the microstructure of the joints and alter the force values that are obtained.

2. Place the sample on the x-y table that is mounted on the constant angle fixture. The clips on the x-y table should then be used to secure the sample to the table. See Figure 1.

Figure 1: Placement of Sample on X-Y Table



3.3 TESTING

1. Set both the upper and lower stops, located on the limit switch, to prevent any damage to the Instron or to the operator. These stops prevent the crosshead from moving past a preset limit in either direction and should be set to prevent the clamp from contacting the substrate.

   When using auto return, the reset should be set to 0 at the point to which the crosshead returns. This reset should be done in conjunction with the use of the stops.

2. Proceed with testing when the sample is mounted, and the safety checks and calibration are completed. The vision system (either CDD camera or stereomicroscope) is swung into position so that the lead to be pulled may be viewed. Note that with the feedback wire attached to the back of the crosshead, the sample must be oriented with the *toe* of the joint pointing toward the front of the machine. This position allows the 90-degree angle to be preserved throughout the test.

3. Move the x-y table to place the lead to be tested between the jaws. Now the clamp is in position. Activate the air actuation mechanism (air pressure between 10 and 20 psi to start, but this pressure should be tested on representative leads prior to test). The lead should now be clamped securely, but torsional, shear, and excessive tensile forces should be avoided.

4. Set the crosshead speed at 0.2 inch per minute. A speed of 0.02 inch per minute is allowed only if comparison with historical data obtained at this speed is required.

   Set the chart speed at 5 inches per minute. This setting is not as critical as the crosshead, but it should allow for a clear documentation of the force/time curve. Extension reading should be 0, the test direction in the up position, and the chart control button in the automatic mode.

5. Recheck the positioning of this setup as erroneous readings or damage to the equipment may result.

6. Obtain the typical load/time curve once the lead is pulled. Failure should be examined in order to check the failure mode (for instance, bond broke, lead broke, or pad lifted). The gripper should then be opened, repositioned over the next lead to be tested, and the next test started. It is important the crosshead speed, full-scale reading, chart speed, and lead number be recorded on the chart in order to fully identify the test.

4 SAMPLE DATA AND STATISTICAL ANALYSIS

For each sample, the component pitch and type, as well as the widths of one lead and one pad, should be specified along with the data. This data should also include the average, maximum, minimum, and standard deviation values for the pull strength data.

The data summary should be presented in both U.S. customary units (lb) and SI units (N); 4.5 N = 1.0 lb may be used as the conversion factor. Data should be reported to the nearest 0.1 lb and to the nearest 0.1 N.

It is recommended that testing be performed until a confidence level of 90% is either reached or exceeded. It is also recommended that detection levels be no smaller than 0.05 lb, and that they generally be 0.1 lb.

The minimum number of leads that need to be tested to assure a given confidence level may be described as:

$$N = (\frac{Z \cdot SD}{D})^2$$

N = Number of samples to be tested.

Z = Constant that depends upon chosen confidence level and number of degrees of freedom, taken from a standard double-sided t-table. The constant assumed to be 1.96 for a confidence level of 95% and 1.64 for a confidence level of 90%.

SD = Standard deviation for a particular test.

D = Detection level of a particular test, based upon error estimate for a particular test and the level of significance required.

See H. M. Wadsworth, *Handbook of Statistical Methods for Engineers and Scientists*, McGraw-Hill, 1990, pp. 9.15 to 9.18.

Table 1 provides typical testing numbers for both 95% and 90% confidence levels, with an assumed detection limit of 0.1 lb and standard deviation values that range from 0.2 lb to 0.4 lb. These numbers are independent of package style and reflow process used, and they are only provided to show the relationship between data scatter, confidence level, and number of tests performed.

Table 1: Estimated Number of Solder Joint Pull Tests for a Given Confidence Level (95% and 90%)

Standard Deviation (lb)	95% Confidence Level No. of Pull Tests	90% Confidence Level No. of Pull Tests
0.2	15	11
0.3	35	24
0.4	62	43
0.5	96	67

It is impossible to know the number of leads that need to be tested until after the degree of data scatter is measured. For this reason, flexibility is recommended.

1. Pull a sample of 20 to 30 leads for a given package type.
2. Measure the standard deviation.
3. Calculate the confidence level.
4. Pull more leads as required.

5 RESPONSIBLE PERSONS

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APPENDIX A REFERENCED DOCUMENTS

H. M. Wadsworth, *Handbook of Statistical Methods for Engineers and Scientists*, McGraw-Hill, 1990

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